U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Nanowire Photovoltaics Based on Abundant, Low-cost Materials and Processing

Neil P. Dasgupta and Peidong Yang

Department of Chemistry, University of California at Berkeley, Berkeley, CA 94720

Background and Introduction

The current PV market is dominated by crystalline Si cells, which can achieve efficiencies of ~24%, but are expensive to manufacture due to high material costs. To achieve the target goal of the DOE's SunShot Initiative of 1 $/watt installed by 2020 will require new manufacturing techniques based on low-cost materials and processing. This project proposes to study nanowire (NW) architectures based on abundant materials with reduced material thickness and purity requirements, without the need for high temperature or high vacuum processing.

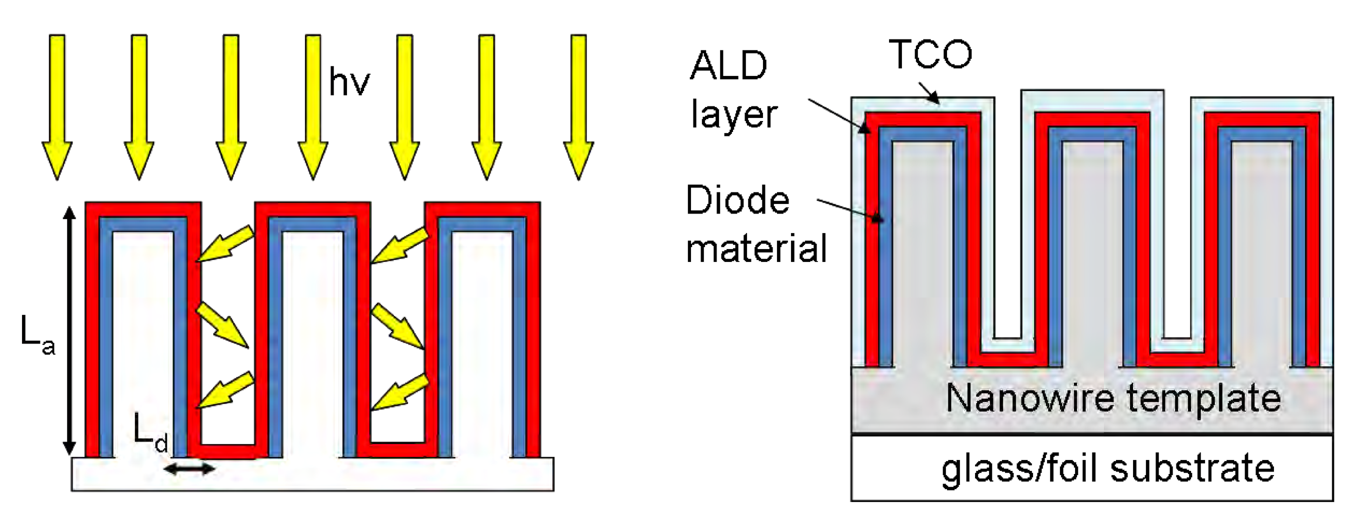
➢ By utilizing NW templates, the absorption length (L_a) required to fully utilize the solar spectrum can be decoupled from the carrier extraction length (L_d), which should be minimized to avoid recombination.

➢ Additionally, NW arrays suppress reflection and enhance light scattering, permitting the use of less material than a planar architecture and reducing the purity and morphological requirements of the absorber layer.

➢However, the ability to uniformly deposit pinhole-free materials on a wide-variety of high-aspect-ratio structures with nanoscale precision is difficult to achieve by traditional processing techniques

➢We propose the use of Atomic Layer Deposition (ALD) in combination with NW templates to fabricate PV devices based on low-cost, abundant materials using scalable manufacturing processes

➢The final device architecture is a PV device fabricated by solution or vapor phase growth, coated by ALD layer(s) to assist in charge separation and extraction.



(left) Light scattering and trapping in nanowire arrays (right) ALD-nanowire solar cell architecture

Approach

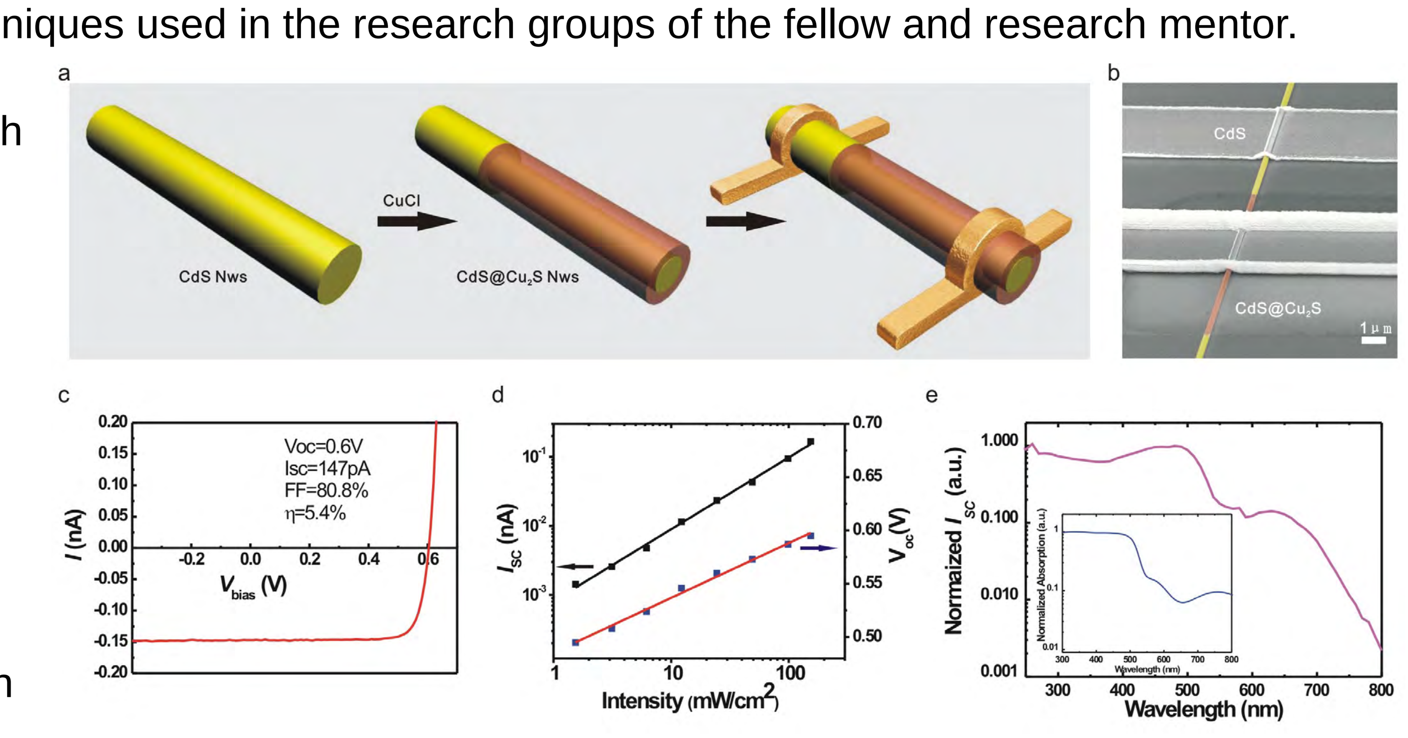
The device fabrication will consist of well-established techniques used in the research groups of the fellow and research mentor.

➢ Low-cost NW fabrication techniques will be explored with an emphasis on solution processing.

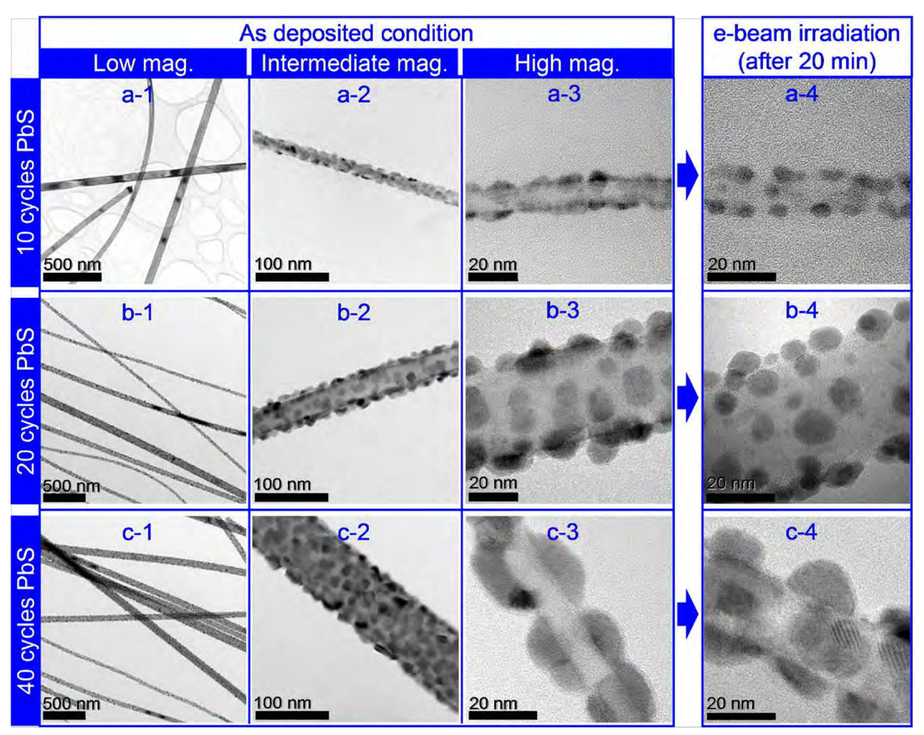
➢ NW materials of interest include semiconductors (Si, ZnO, CdS, Cu_2S, Cu_xO, InGaN, TiO_2) and metals (Cu, Ni, Ni_xSi)

➢ We will target the use of inexpensive and flexible substrates such as metal foils and polymers, compatible with large-scale manufacturing

➢ Both single-NW and array devices will be studied to gain insight into the fundamental properties of these materials.



CdS-Cu_2S core-shell nanowire PV devices fabricated at UC Berkeley
Tang, J., Huo, Z., Brittman, S., Gao, H. & Yang, P., *Nature Nanotech*. **6**, 568 (2011)



TEM images of Si NWs coated by PbS QDs deposited by ALD with various cycle numbers
Dasgupta, N. P. et al., *Nano Lett.* **11**, 934 (2011)

➢ Once the NW template has been fabricated, a core-shell structure will be fabricated using techniques capable of creating a conformal coating

➢ ALD layers will be explored as coating materials, due to their favorable properties (high aspect ratios, pinhole free, material variety, low T deposition)

➢ ALD layers of interest include oxide and sulfide semiconductors (ZnO, TiO_2, SnO_2, Cu_xO, SnS, Cu_xS, CdS), transparent electrode materials and metals.

➢ Other low-cost coating techniques will be explored, with an emphasis on solution based processing

➢ Prototype devices will be characterized by I-V, quantum efficiency, absorption/reflection, photoluminescence, photocurrent mapping etc.

➢Fundamental materials characterization by high-resolution microscopy and spectroscopy techniques to study electrical, optical, chemical properties

Impact

This project will make several contributions to the targeted goals of the $1/Watt SunShot initiative by lowering module manufacturing costs through reduction of material volume and purity requirements, and exploring new material systems based on abundant elements. The target module cost is $0.50/watt. To obtain this goal, high-efficiency modules (>25%) must be developed using low-cost techniques. Major cost reductions are available in reducing raw material use and expensive processing techniques such as high vacuum or temperatures. The use of abundant elements, low-cost flexible substrates, reduced material thickness, solution-based processing, and ALD eliminates many of these cost barriers while maintaining high efficiencies due to the benefits of nanostructuring.

Acknowledgments

This fellowship is supported by the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Postdoctoral Research Awards under the SunShot Solar Energy Technologies program. The CdS/Cu_2S work was supported by the Director, Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division, of the U.S. DOE (contract no. DE-AC02-05CH11231).

Nanowire architectures can lower manufacturing costs by reducing material thickness and purity requirements, enabling new systems based on abundant elements